

What is claimed is:

1. A process for etching copper and copper alloys which comprises:
 - a) contacting an exposed copper or copper alloy surface with an aqueous etching composition that comprises an oxidant, a mixture comprising at least one weak complexant for the copper or copper alloy having a cumulative stability constant with copper of $\leq 10^{14}$ and at least one strong complexant for the copper or copper alloy having a cumulative stability constant with copper of $\geq 10^{15}$, and water and has a pH of about 6 to about 12 so as to form an oxidizable etch controlling layer of a copper compound 2, and to remove the copper or copper alloy; and
 - 10 b) then contacting the structure with a non-oxidizing composition for removing the oxidizable etch controlling layer.
2. The process of claim 1 wherein the etching composition comprises at least one peroxide compound and at least one weak complexant for copper or copper alloy selected from the group consisting of ammonia and an amine; and at least one strong complexant for the copper or copper alloy selected from the group consisting of an aminocarboxylate and an aminophosphonate; and has a basic pH.
- 15 3. The process of claim 2 wherein the peroxide is selected from the group consisting of hydrogen peroxide, a peroxy carboxylate, perborate, and percarbonate, and mixtures thereof.
- 20 4. The process of claim 3 wherein the at least one weak complexant is selected from the group consisting of ammonia, ethylamine, methylamine, tetramethylammonium hydroxide and 2-hydroxyethyl-trimethylammonium hydroxide; and the at least one strong complexant is

selected from the group consisting of 1, 2-cyclohexane diaminetetraacetic acid (CDTA), ethylene diamine tetraacetic acid (EDTA), triethylenetetraaminehexaacetic acid; diethylene triaminepentaacetic acid; 2,2-dimethyl-1,3-diaminopropane-N,N,N',N'-tetraacetic acid; cis, cis,cis-3,5-dimethyl-1,2-diaminocyclopentane-N,N,N',N'-tetraacetic acid and cis-bicyclo (2.2.2) octane-2,3-diamine -N,N,N',N'-tetraacetic acid.

5. The process of claim 2 wherein the at least one weak complexant is selected from the group consisting of ammonia, ethylamine, methylamine, tetramethylammonium hydroxide and 2-hydroxyethyl-trimethylammonium hydroxide; and said strong complexant is selected from the group consisting of 1, 2-cyclohexane diaminetetraacetic acid (CDTA), ethylene diamine tetraacetic acid (EDTA), triethylenetetraaminehexaacetic acid; diethylene triaminepentaacetic acid; 2,2-dimethyl-1,3-diaminopropane-N,N,N',N'-tetraacetic acid; cis, cis,cis-3,5-dimethyl-1,2-diaminocyclopentane-N,N,N',N'-tetraacetic acid and cis-bicyclo (2.2.2) octane-2,3-diamine - N,N,N',N'-tetraacetic acid.

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6. The process of claim 1 wherein the etching composition comprises about 0.5 to about 10 wt% of said oxidant, about 0.1 Molar to about 0.8 Molar of the weak complexant, and about 0.001 to about 10 g/l of the strong complexant.

20 7. The process of claim 1 wherein the oxidant comprises hydrogen peroxide and said complexant comprises ammonia.

8. The process of claim 7 wherein the etching composition comprises about 0.001-10g/l of 1,2-cyclohexane diaminetetraacetic acid, ethylene diamine tetraacetic acid or both.

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9. The process of claim 1 wherein the etching composition comprises about 1.5 wt% hydrogen peroxide, about 0.5 wt% ammonia and about 0.5 g/l of 1,2-cyclohexane-diaminetetraacetic acid.
- 5 10. The process of claim 1 wherein the etching composition comprises about 3 wt% hydrogen peroxide, about 0.5 wt% ammonia and about 0.5 g/l of 1,2-cyclohexane-diaminetetraacetic acid.
11. The process of claim 10 wherein the etching composition further comprises a non-oxidizing acid or salt thereof or a base.
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12. The process of 11 wherein the non-oxidizing acid is selected from the group consisting of sulfuric acid, hydrochloric acid, acetic acid and methanesulfonic acid and mixtures thereof and said base is selected from the group consisting of sodium hydroxide, potassium hydroxide, and
- 15 tetramethyl ammonium hydroxide and mixtures thereof.
13. The process of claim 1 wherein the etching composition further comprises a non-oxidizing acid or salt thereof or a base.
- 20 14. The process of 13 wherein the non-oxidizing acid is selected from the group consisting of sulfuric acid, hydrochloric acid, acetic acid and methanesulfonic acid and mixtures thereof and said base is selected from the group consisting of sodium hydroxide, potassium hydroxide, and tetramethyl ammonium hydroxide and mixtures thereof.

15. The process of claim 1 wherein the non-oxidizing solution comprises a deaerated non-oxidizing aqueous acid.
16. The process of claim 15 wherein the acid is at least one member selected from the group
5 consisting of sulfuric acid, hydrochloric acid, acetic acid and methanesulfonic acid.
17. The process of claim 1 wherein further comprises rinsing the non-oxidizing solution from the structure with at least one non-reactive solvent.
- 10 18. The process of claim 1 which further comprises rinsing, drying, and storing the structure between a) and b).
19. An etched copper or copper alloy surface obtained by the process of claim 1.
- 15 20. A process for generating copper or copper alloy electrical interconnects or contact pads which comprises:
- a. depositing a blanket copper or copper alloy film on a dielectric substrate;
 - b. depositing a thin film of photoresist over the copper or copper alloy film;
 - c. exposing and developing the photoresist through a mask design to generate the
20 negative image of the desired copper or copper alloy.
 - d. etching away copper or copper alloy exposed in c by the process of claim 1; and
 - e. stripping the resist to reveal the desired copper or copper alloy pattern.

21. The process of claim 20 wherein the copper or copper alloy has a sidewall surface with an average roughness of about 3 nanometers or less.
22. A copper structure comprising copper or copper alloy surface and an oxidized etch
5 controlling layer, the etch controlling layer having a uniform thickness of about 2 to about 1000 nanometers and adhered to the copper or copper alloy surface.
23. The structure of claim 22 wherein the etch controlling layer is a hydrated copper oxide
layer.
- 10 24. The structure of claim 22 wherein the etch controlling layer is obtained by contacting an exposed copper or copper alloy surface with an aqueous etching composition that comprises an oxidant, a complexant for the copper or alloy, and water and has a pH of about 6 to about 12.
- 15 25. The structure of claim 22 being copper containing electrical interconnects or contact pads
26. The structure of claim 22 wherein the copper or alloy is recessed relative to the top of surrounding dielectric material.
- 20 27. A dielectric-copper or copper alloy structure comprising copper or alloy thereof conformally recessed relative to the top of surrounding dielectric material, and having a surface with an average roughness of about 3 nanometers or less.

28. The structure of claim 27 wherein the copper or alloy thereof has a thickness of at least about 5.
29. An aqueous etching composition having a pH of about 6 to about 12 and comprising about 0.5 to about 10 wt% of an oxidant; a mixture comprising at least one weak complexant for the copper or copper alloy having a cumulative stability constant with copper of $\leq 10^{14}$ and at least one strong complexant for the copper or copper alloy having a cumulative stability constant with copper of $\geq 10^{15}$, the amount of the at least one weak complexant is about 0.1 Molar to about 0.8 Molar, and the amount of the at least one strong complexant is about 0.001 to about 10 g/l; and water.
30. The etching composition of claim 29 which comprises at least one peroxide compound and at least one weak complexant for copper or copper alloy selected from the group consisting of ammonia and an amine; and at least one strong complexant for the copper or copper alloy selected from the group consisting of an aminocarboxylate and an aminophosphonate; and has a basic pH.
31. The etching composition of claim 30 wherein the peroxide is selected from the group consisting of hydrogen peroxide, a peroxy carboxylate, perborate, and percarbonate, and mixtures thereof.
32. The etching composition of claim 31 wherein the at least one weak complexant is selected from the group consisting of ammonia, ethylamine, methylamine, tetramethylammonium hydroxide and 2-hydroxyethyl-trimethylammonium hydroxide; and the at least one strong complexant is selected from the group consisting of 1, 2-cyclohexane diaminetetraacetic acid (CDTA), ethylene diamine tetraacetic acid (EDTA), triethylenetetraaminehexaacetic acid; diethylene triaminepentaacetic acid; 2,2-dimethyl-1,3-diaminopropane-N,N,N',N'-tetraacetic acid; cis, cis,cis-3,5-dimethyl-1,2-diaminocyclopentane-N,N,N',N'-tetraacetic acid and cis-bicyclo (2.2.2) octane-2,3-diamine -N,N,N',N'-tetraacetic acid.

33. The etching composition of claim 29 wherein the oxidant comprises hydrogen peroxide and said complexant comprises ammonia.
34. The etching composition of claim 33 which comprises about 0.001-10g/l of 1,2-cyclohexane diaminotetraacetic acid, ethylene diamine tetraacetic acid or both.
- 5 35. The etching composition of claim 29 which comprises about 1.5 wt% hydrogen peroxide, about 0.5 wt% ammonia and about 0.5 g/l of 1,2-cyclohexane- diaminotetraacetic acid.
36. The etching composition of claim 29 which comprises about 3 wt% hydrogen peroxide, about 0.5 wt% ammonia and about 0.5 g/l of 1,2-cyclohexane diaminotetraacetic acid.
37. The etching composition of claim 29 which further comprises a non-oxidizing acid or salt
10 thereof or a base.
38. The etching composition of 37 wherein the non-oxidizing acid is selected from the group consisting of sulfuric acid, hydrochloric acid, acetic acid and methanesulfonic acid and mixtures thereof and said base is selected from the group consisting of sodium hydroxide, potassium hydroxide, and tetramethyl ammonium hydroxide and mixtures thereof.
- 15 39. The etching composition of claim 1 which comprises a deaerated non-oxidizing aqueous acid.